

# Recent Bridge Deck Cracking Incidents

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# Bridge Deck Cracking

- ◆ Review of Specifications
- ◆ Review of Photos from
  - ◆ Tule River Bridge
  - ◆ Ash Slough Bridge
  - ◆ FR2 Connector at Rte 41
  - ◆ St. John's River Bridge
- ◆ Current Practices
- ◆ Questions

# Bridge Deck Cracking



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# Bridge Deck Cracking





# Bridge Deck Cracking

## Specifications

**90-7.03 Curing Structures.**—All newly placed concrete for cast-in-place structures, other than highway bridge decks, shall be cured by the water method, ... or ... all in accordance with the requirements in Section 90-7.01, “Methods of Curing.”

...

# Bridge Deck Cracking

## Specifications

### 90-7.03 Curing Structures.— ...

The top surface of highway bridge decks shall be cured by both the curing compound method, and by the water method. The curing compound shall be curing compound (1). The curing compound shall be applied progressively during the deck finishing operations immediately after finishing operations are completed on each individual portion of the deck. The water cure shall be applied not later than 4 hours after completion of deck finishing or, for portions of the decks on which finishing is completed after normal working hours, the water cure shall be applied not later than the following morning.

# Bridge Deck Cracking

## Specifications

**90-7.01A Water Method.**—The concrete shall be kept continuously wet by the application of water for a minimum period of 7 days after the concrete has been placed.

Cotton mats, rugs, carpets, or earth or sand blankets may be used as a curing medium to retain the moisture during the curing period.

When cotton mats, rugs, carpets, or earth or sand blankets are to be used to retain the moisture, **the entire surface of the concrete shall be kept damp** by applying water with a nozzle that so atomizes the flow that a mist and not a spray is formed, **until the surface of the concrete is covered ...**



## Specifications

### 90-7.01B Curing Compound Method.— ...

The curing compound shall be applied to the concrete following the surface finishing operation **immediately before the moisture sheen disappears from the surface**, but before any drying shrinkage or craze cracks begin to appear. **In the event of any drying or cracking of the surface, application of water with an atomizing nozzle** as specified in Section 90-7.01A, “Water Method,” shall be started immediately and shall be continued until application of the compound is resumed or started; however, the compound shall not be applied over any resulting freestanding water. ...

## Specifications

**90-6.06 Amount of Water and Penetration.**—The amount of water used in concrete mixes shall be regulated so that the consistency of the concrete as determined by California Test 533 is within the nominal penetration range shown in the following table. When the penetration of the concrete is found to exceed the nominal penetration, the mixture of subsequent batches shall be adjusted to reduce the penetration to a value within the nominal range shown. ...

# Bridge Deck Cracking

## Specifications

### 90-6.06 Amount of Water and Penetration.

| <i>Type of Work</i>                     | <i>Nominal<br/>Penetration<br/>(Inches)</i> | <i>Maximum<br/>Penetration<br/>(Inches)</i> |
|---|---|---|
| Concrete Pavement.....                  | 0-1   | 1 ½   |
| Non-Reinforced concrete facilities..... | 0-1 ½                                       | 2   |
| Reinforced concrete structures:         |   |   |
| Sections over 12 inches thick.....      | 0-1 ½                                       | 2 ½   |
| Sections 12 inches thick or less...     | 0-2   | 3   |
| Concrete placed under water.....        | 3-4   | 4 ½   |



# Bridge Deck Cracking

## Specifications

**51-1.01 Description**—The work shall consist of constructing concrete bridges, grade separations, structure approach slabs, ... and all other types of Portland cement concrete structures to the lines and grades established by the Engineer and in accordance with the designs and details shown on the plans and as specified in these specifications and the special provisions. Concrete shall conform to the provisions in Section 90, ‘Portland Cement Concrete,’ of these specifications.”

# Bridge Deck Cracking

## Specifications

**51-1.17 Finishing Bridge Decks.**—The completed roadway surfaces of structures, approach slabs and adjoining approach pavement, and the top surfaces of concrete decks which are to be covered with an-other material, shall be constructed true to the required grade and cross section and to the smoothness, surface texture **and surface crack requirements specified herein.**

...

# Bridge Deck Cracking

## Specifications

### 51-1.17 Finishing Bridge Decks.— ...

The surface crack intensity of concrete bridge decks is indicated by the number and size of shrinkage cracks in the top surface of the concrete. The Contractor shall use the proper combination of low shrink materials, low temperature concrete, low penetration concrete, revibration or refloating finishing techniques, fog sprays during finishing, or other procedures as necessary to eliminate or minimize the development of such cracks. The Contractor shall remove all equipment and materials from the deck and clean the surface as necessary for the Engineer to measure the crack intensity. ...



## ◆ 51-1.17, Finishing Bridge Decks

- ◆ The Contractor shall use the proper combination
  - ▶ Low shrink materials
  - ▶ Low temperature concrete
  - ▶ Low penetration concrete
  - ▶ Revibration or refloating finishing techniques
  - ▶ Fog sprays during finishing
  - ▶ Other procedures as necessary to eliminate or minimize the development of such cracks

# Specifications

## 51-1.17 Finishing Bridge Decks.— ...

... Surface crack intensity will be determined after completion of concrete cure and prior to prestressing or release of falsework. In any 500 square foot portion of deck, should the intensity of cracking be such that there are more than 50 linear feet of cracks whose width at any location exceeds 0.020-inch, all such cracks in that portion shall be filled with pressure injected epoxy.

... filled by pressure injection methods so that all portions of the crack which are wider than 0.005-inch are completely filled with epoxy.

# Bridge Deck Cracking

## Tule River Bridge

### ◆ 2 Stages

#### ◆ Stage 1 – Significant deck cracking

- ▶ Up to 250LF per 500 SF

#### ◆ Stage 2 – No significant cracking

- ▶ All areas less than 50LF per 500SF



Bridge

Deck

Cracking

## Tule River Br. - Stage 1

◆ 4061psi 8sk mix with 25% Fly ash

- ◆ Type II PC - 563lbs
- ◆ Type F Fly ash - 188lbs
- ◆ Sand - 1072lbs
- ◆ 1"X4 Coarse Agg (combined) - 1859lbs
- ◆ Water - 323lbs
- ◆ ASTM Type A Water Reducer - 37.55oz

MB 300N at 5oz/100lbs cementitious

◆ Design slump 3"       $W/C = 0.43$

Bridge

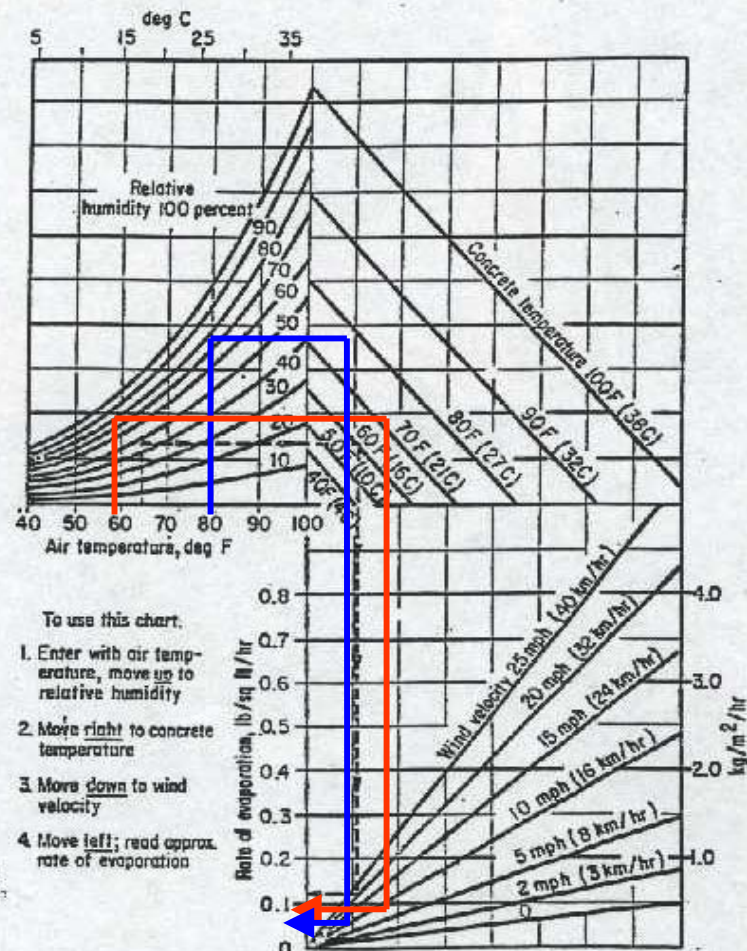
Deck

Cracking

## Tule River Br. - Stage 1

- ◆ Actual placement condition – 5/2/00
  - ◆ Placed concrete at temp of 72-77°
  - ◆ Air temp between 62-80°
  - ◆ Penetration up to 1  $\frac{3}{4}$  "
  - ◆ W/C = 0.35
  - ◆ Evaporation rate of 0.06-0.08
  - ◆ Curing compound sampled the day of the pour failed to meet the conformance testing with only about 80% solids

Effect of concrete and air temperature, relative humidity, and wind velocity as the ratio of evaporation of surface moisture from concrete. This chart provides a graphic method of estimating the loss of surface moisture for various weather conditions. To use the chart, follow the four steps outlined above. If the ratio of evaporation approaches 0.2 lb/ft<sup>2</sup>/hr (1.0 kg/m<sup>2</sup>/hr), precaution against plastic shrinkage cracking are necessary



BRIDGE CONSTRUCTION MEMO 105-4.0

Bridge  
Deck  
Cracking

## Tule River Br. - Stage 1





Bridge  
Deck  
Cracking

# Tule River Br. - Stage 1



Bridge  
Deck  
Cracking

# Tule River Br. - Stage 1





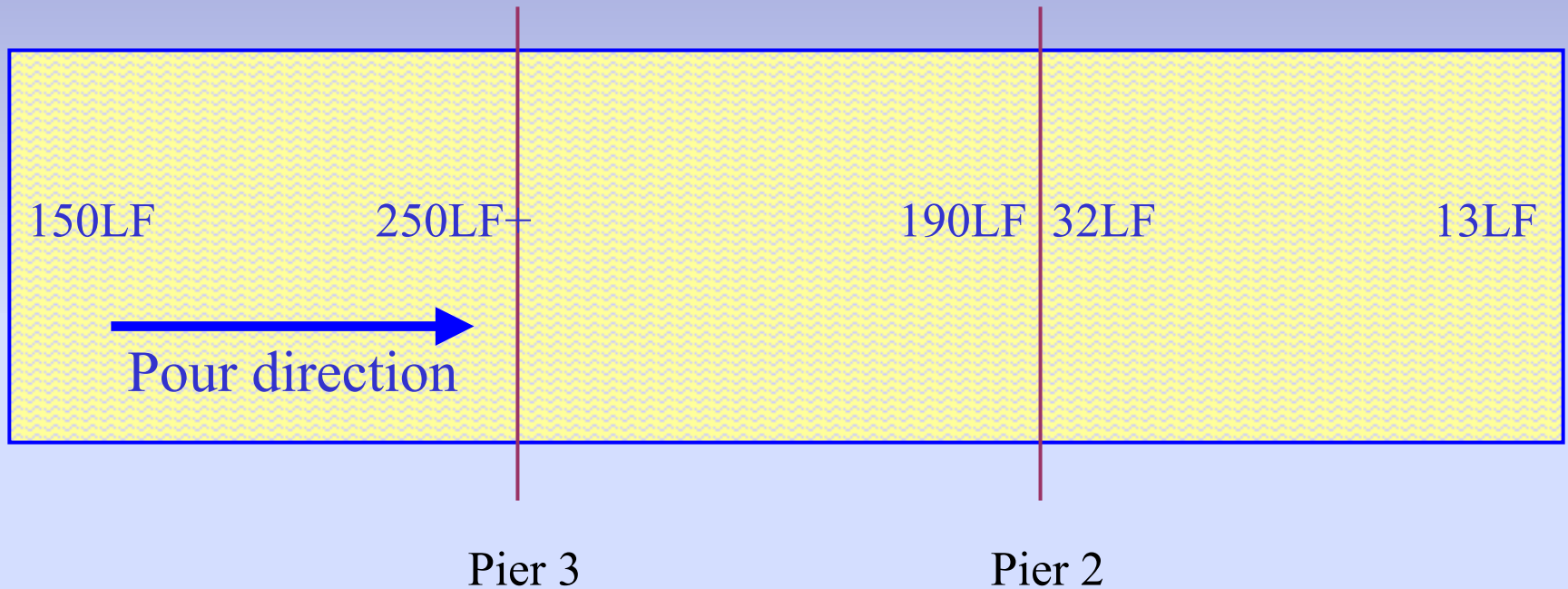
Bridge  
Deck  
Cracking

# Tule River Br. - Stage 1



# Bridge Deck Cracking

## Tule River Br. - Stage 1





Bridge  
Deck  
Cracking

# Tule River Br. - Stage 1



Bridge  
Deck  
Cracking

## Tule River Br. - Stage 1





Bridge  
Deck  
Cracking

# Tule River Br. - Stage 1



## Tule River Br. - Stage 2

- ◆ Actual placement condition – 8/01
  - ◆ A WR product designed for Fly ash
    - ▶ MB Polyheed FC 100
  - ◆ Water cure began promptly
    - ▶ Fogging machine was used
  - ◆ Air temperature mid 50°s to mid 90°s
  - ◆ Allowed concrete temp up to 90° max



Bridge  
Deck  
Cracking

# Tule River Br. - Stage 2



## Tule River Br. - Stage 2

### **POLYHEED® FC100**

*Mid-range water-reducing admixture*

#### **DESCRIPTION:**

**POLYHEED® FC100** ready-to-use non-chloride, mid-range water-reducing admixture is a new generation of admixture based on GLENIUM™ Technology. **POLYHEED FC100** admixture is specifically formulated to provide normal setting times with fly ash and or ground granulated blast-furnace slag (GGBFS) concrete mixtures.

**POLYHEED FC100** admixture meets ASTM C 494 requirements for Type A, water-reducing, admixtures, Type C, accelerating, admixtures and Type E, water-reducing and accelerating, admixtures. **POLYHEED FC100** admixture provides true mid-range water reduction (5 to 18%) and excellent performance across a wide slump range, especially the difficult slump range of 6 to 8 in. (150 to 200 mm).

# Bridge Deck Cracking

## Tule River Br. - Stage 2

### QUANTITY TO USE:

POZZOLITH 300-N admixture is recommended for use at a rate of 3 to 5 fl oz per 100 lb (195 to 325 mL per 100 kg) of cement for most concrete mixes using average concrete ingredients. Because of variations in job conditions and concrete materials, dosage rates other than the recommended amounts may be required. In such cases, consult your local Master Builders representative.

### QUANTITY TO USE:

**POLYHEED FC100** mid-range water-reducing admixture has a recommended dosage range of 8 to 30 fl oz per 100 lb (520 to 1,950 mL per 100 kg) of total cementitious for most concrete mixes.

Master Builders does not recommend the use of dosage rates outside the recommended range without trial testing. Consult your local Master Builders representative for assistance in determining the dosage rate for optimum performance.

Bridge  
Deck  
Cracking

## FR2 OC at Route 41

### ◆ 2 Stage deck pour

#### ◆ Stage 1 – poured 3/21/00

- ▶ Significant deck cracking

#### ◆ Stage 2 – poured 3/24/00

- ▶ Significant deck cracking

#### ◆ Third bridge, Ave 11 UC – poured 3/28/00

- ▶ Significant deck cracking

Bridge  
Deck  
Cracking

## FR2 OC at Route 41

◆ 4000psi 7sk mix with 25% Fly ash

- ◆ Type II PC – National Lebec - 494lbs
- ◆ Type F Fly ash Pozzolanic - 165lbs
- ◆ Sand - 1176lbs
- ◆ 1"X4 Coarse Agg - 1798lbs
- ◆ Water - 310lbs
- ◆ ASTM Type A Water Reducer - 32.90oz

MB 300N at 5oz/100lbs cementitious

◆ Design slump 4"      $W/C = 0.47$

Bridge  
Deck  
Cracking

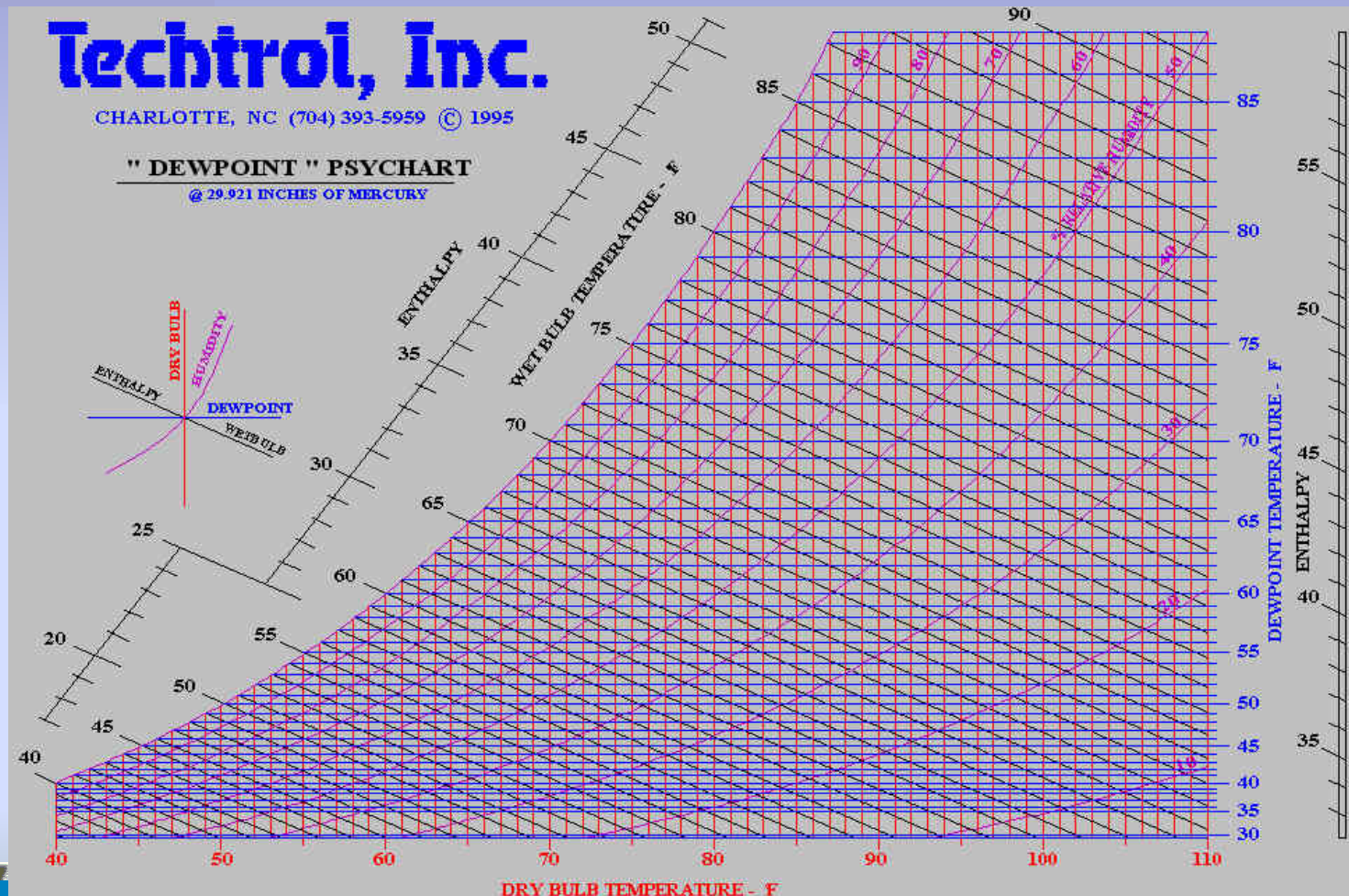
## FR2 OC at Route 41

- ◆ Actual placement condition
  - ◆ Placed concrete at temp of 70-72°
  - ◆ Air temp between 60-80°
  - ◆ Penetration up to 2 ½ " (Approx 5" slump)
  - ◆ W/C = 0.36
  - ◆ Evaporation rate of about 0.12

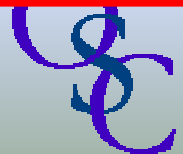
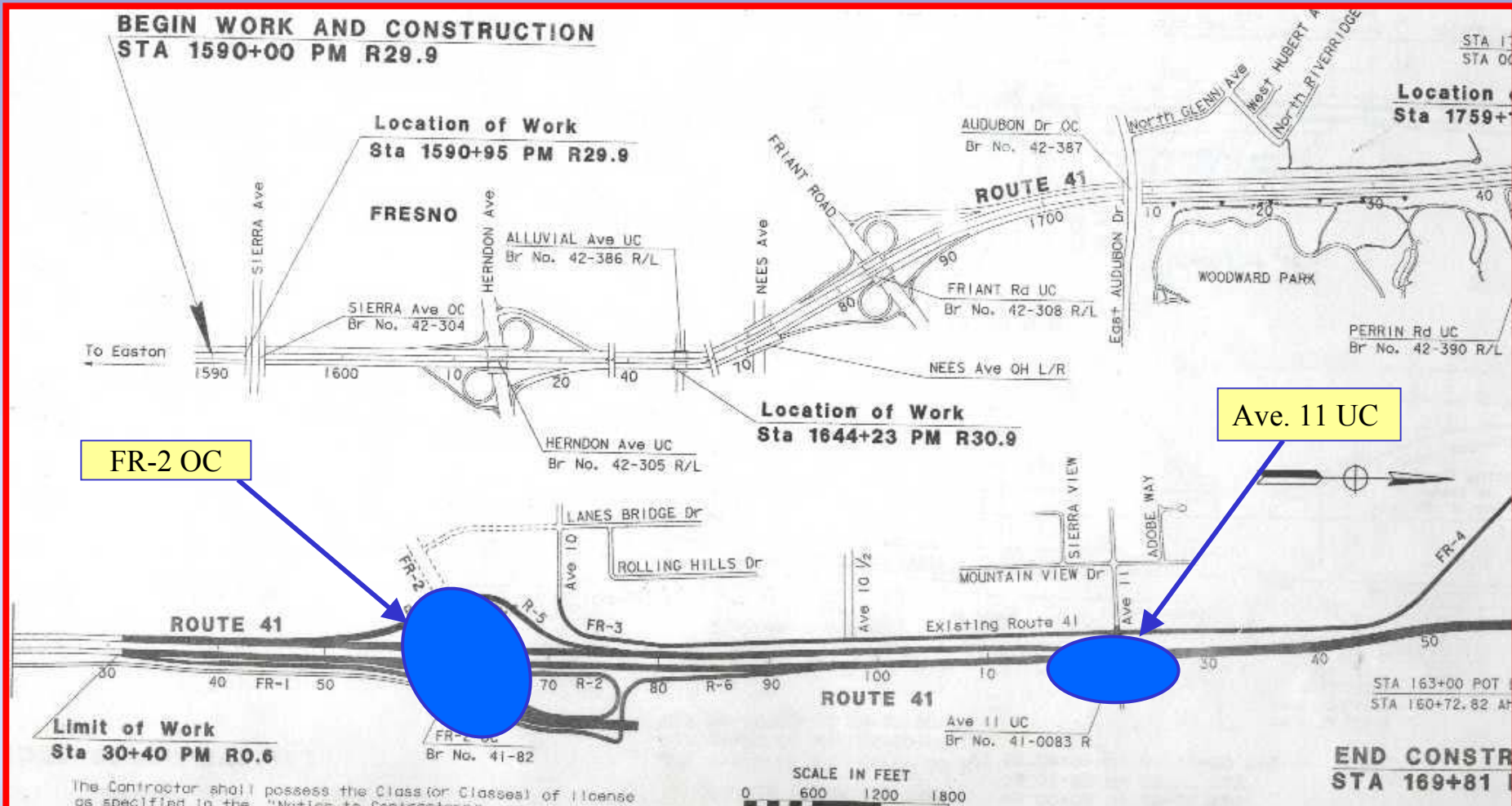


# Bridge Deck Cracking

## FR2 OC at Route 41



# FR2 OC at Route 41





# Bridge Deck Cracking





# Bridge Deck Cracking

FR 2  
LEFT DECK  
NORTH  
3-21-00



# Bridge Deck Cracking

## Concrete Pour Record Bridge FR2 Dated 03-21-2000

| CONCRETE POUR RECORD  |         |          |          |           |                           |           |       |                        |         |
|---|---------|----------|----------|-----------|---------------------------|-----------|-------|------------------------|---------|
| Sheet Number: <u>48 - 61 - 14 - FR2</u>   |         |          |          |           | (Cat Item# Sheet# Str ID) |           |       |                        |         |
| Job Stamp:<br>06-305514 HP 21-1191(001)E<br>06-FRE,MAD-41-R29.9/R33.5,RO.O/R3.2<br>FROM SIERRA AVE OC TO AVENUE 12  |         |          |          |           |                           |           |       |                        |         |
| Bridge Name: <u>FR2</u> Bridge No: <u>41-0082</u><br>Item No. and Description: # <u>61 STRUCTURE CONCRETE BRIDGE</u><br>Date: <u>03-21-00</u> Mix No.: <u>99075</u> Certificate of Comp No's.: <u>327303, 106, 102, 104, 096, 326132</u><br>Pour Location: <u>DECK, LEFT SECTION</u><br>Admixutre Used: <u>POZZ 300-N</u> Amount: <u>32.9 OZ/CY</u><br>Air Entraining Agent: _____ Amount: _____ % Air Required _____<br>Pour Inspected By: <u>J. BUNNUEE, M. MTRZAT</u> Samples By: <u>M. MTRZAT</u><br>Sample Numbers: <u>SET1: 1-14-1&amp;2 of 2, 1-28-1&amp;2 of 2, SET2 : 1-14-1&amp;2 of 2, 1-28-1&amp;2 of 2</u> |         |          |          |           |                           |           |       |                        |         |
| Time  | Load No | Truck No | Air Temp | Conc Temp | Individual Penet Readings | Ave Penet | % Air | Tests By               | Remarks |
| 0715  | 12      | 11       | 65       | 20C       | 2.5, 2.25, 2.75           | 2.5       |       | MM                     |         |
| 1245  | 48      | 171      | 71       | 21C       | 1.5, 1.5, 1.5             | 1.5       |       | MM                     |         |
|   |         |          |          |           |                           |           |       |                        |         |
| Total Quantity To Date, This Item This Bridge: <u>3045.5</u> CY.  |         |          |          |           |                           |           |       | This Pour <u>688.5</u> |         |

# Bridge Deck Cracking

Concrete Pour Record  
Bridge FR2  
Dated 03-24-2000

**CONCRETE POUR RECORD**

Sheet Number: 48 - 61 - 15 - FR2  
(Cat Item Sheet Str ID)

Job Stamp:  
06-305514 HP 21-1191(001)E  
06-FRE,MAD-41-R29.9/R33.5,RO.O/R3.2  
FROM SIERRA AVE OC TO AVENUE 12

Bridge Name: FR2 Bridge No: 41-0082  
 Item No. and Description: # 61 STRUCTURE CONCRETE BRIDGE  
 Date: 03-24-00 Mix No.: 99075 Certificate of Comp No's.: 326157,326155  
 Pour Location: DECK, RIGHT SECTION  
 Admixutre Used: POZZ 300-N Amount: 32.9 OZ/CY  
 Air Entraining Agent: \_\_\_\_\_ Amount: \_\_\_\_\_ % Air Required \_\_\_\_\_  
 Pour Inspected By: J. BORQUEZ, M. MIREAT Samples By: M. MARZAL, J. BORQUEZ  
 Sample Numbers: SET1:1-14-162 of 2, 1-28-162 of 2, SET2 :1-14-162 of 2, 1-28-162 of 2

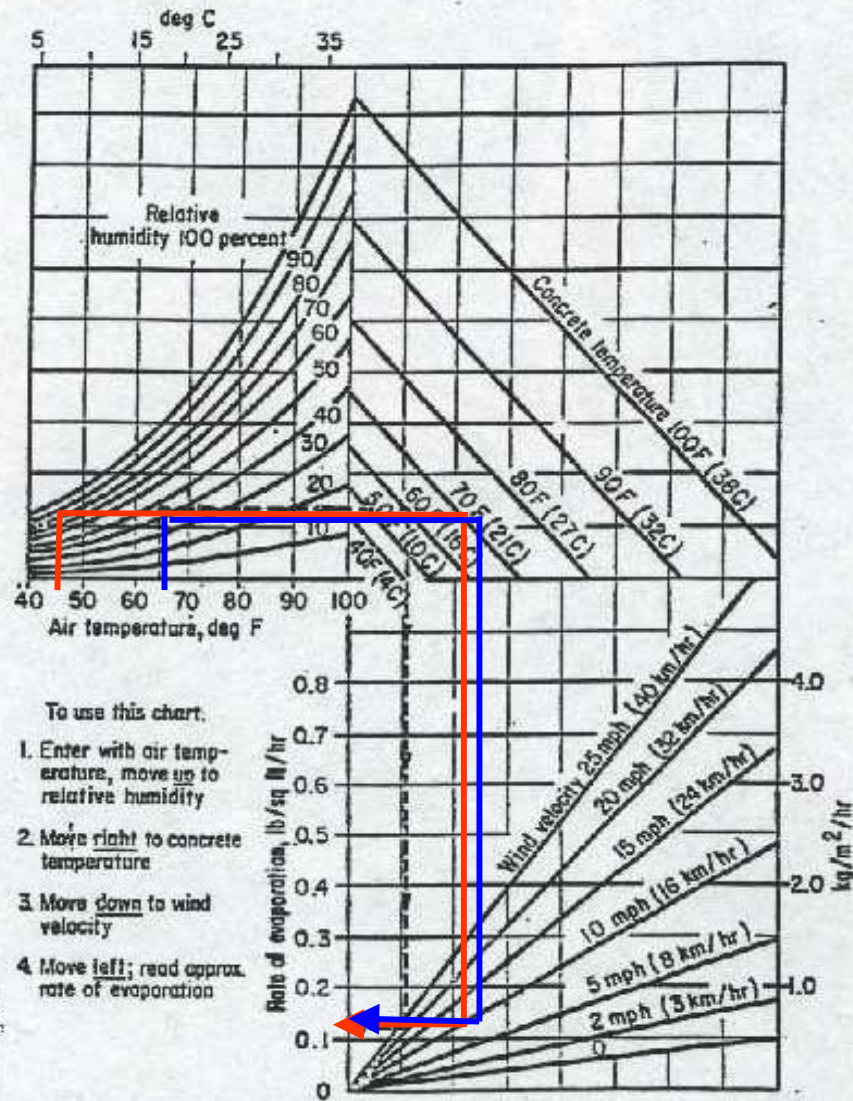
| Time | Load No | Truck No | Air Temp | Conc Temp | Individual Penet Readings | Ave Penet | % Air | Tests By | Remarks |
|------|---------|----------|----------|-----------|---------------------------|-----------|-------|----------|---------|
| 0715 | 10      | 299      | 57       | 20C       | 2.5, 2.25, 2.25           | 2.25      |       | MM       |         |
| 1245 | 41      | 141      | 68       | 20C       | 2.5, 2.5, 2.5             | 2.5       |       | JB       |         |
|      |         |          |          |           |                           |           |       |          |         |
|      |         |          |          |           |                           |           |       |          |         |

Total Quantity To Date, This Item This Bridge: 3615.5 CY. This Pour 570 CY



# Bridge Deck Cracking

## Bridge Construction Memo 105-4.0



- To use this chart.
1. Enter with air temperature, move up to relative humidity
  2. Move right to concrete temperature
  3. Move down to wind velocity
  4. Move left; read approx. rate of evaporation

Effect of concrete and air temperatures, relative humidity, and wind velocity on the rate of evaporation of surface moisture from concrete. This chart provides a graphic method of estimating the loss of surface moisture for various weather conditions. To use the chart, follow the four steps outlined above. If the rate of evaporation approaches 0.2 lb/ft²/hr (1.0 kg/m²/hr), precautions against plastic shrinkage cracking are necessary.

BRIDGE CONSTRUCTION MEMO 105-4.0

Bridge  
Deck  
Cracking

# FR2 OC at Route 41





# Bridge Deck Cracking

## FR2 OC at Route 41



# Bridge Deck Cracking

## FR2 OC at Route 41





# Bridge Deck Cracking

## FR2 OC at Route 41





# Bridge Deck Cracking

## Ash Slough Bridge

### ◆ Placement condition

- ◆ 7 sack mix – no strength requirement
- ◆ Placed early 11/01 – 3 frames
  - ▶ Foggy AMs & sunny PMs
  - ▶ concrete at temp of  $70^{\circ\pm}$
  - ▶ Air temp between  $45-62^{\circ}$
- ◆ Design W/C = 0.43 (in place probably less)
- ◆ MB Pozzoloth 300R at 4oz/100lbs cementitious
- ◆ Slab bridge 18" thick
  - ▶ Placed in two (2) lifts

# Bridge Deck Cracking

## Ash Slough Bridge



# Bridge Deck Cracking

## Ash Slough Bridge





# Bridge Deck Cracking

## Ash Slough Bridge



# Bridge Deck Cracking

## Ash Slough Bridge





# Bridge Deck Cracking

## St John's River Bridge

### ◆ 2 Stages

#### ◆ Stage 1

- ▶ Placed 8/00
- ▶ No significant cracking

#### ◆ Stage 2

- ▶ Placed 9/01
- ▶ No significant cracking

Bridge  
Deck  
Cracking

# St John's River Bridge



Bridge  
Deck  
Cracking

# St John's River Bridge



# Bridge Deck Cracking

## St John's River Bridge





Bridge  
Deck  
Cracking

# St John's River Bridge



Bridge  
Deck  
Cracking

# St John's River Bridge





# Bridge Deck Cracking

## CONCRETE TECHNOLOGY UPDATE



ISSUE # 10

MAY 1997

## SHRINKAGE OF CONCRETE

time. The rate at which bleed water is transported to the concrete surface will impact the potential for the phenomenon or form of cracking commonly referred to as *plastic shrinkage cracking*. It has been reported that if the rate of surface evaporation exceeds about  $0.5 \text{ kg/m}^2/\text{h}$  ( $0.1 \text{ lb/ft}^2/\text{h}$ ), the loss of moisture may exceed the rate at which bleed water reaches the surface, thereby setting into motion

the mechanisms that cause plastic shrinkage [1]. In ACI 305R [2], it is recommended that precautions against plastic-shrinkage cracking should be taken if the evaporation rate from the exposed concrete surface is expected to approach  $1.0 \text{ kg/m}^2/\text{h}$  ( $0.2 \text{ lb/ft}^2/\text{h}$ ). The evaporation rate for a prevailing ambient condition can be estimated by using the nomograph shown in Fig. 1.

Precautionary measures to control plastic shrinkage include adjustments to the concrete mixture and the use of proven construction techniques.

Reducing the temperature of a concrete mixture, particularly in hot weather, or increasing its rate of setting can be beneficial. The latter is one of the primary reasons why accelerating admixtures, such as POZZUTEC 20 admixture, are increasingly being used in the arid Southwest Regions, where conditions for plastic shrinkage are prevalent. The use of FIBERMESH® polypropylene fibers has also been reported to be beneficial in controlling plastic shrinkage cracking [3].

Effective construction practices to control plastic shrinkage include the use of temporary windbreaks and sunshades to reduce wind velocity and concrete surface temperatures, respectively, and placing concrete at the coolest time of day. But by far, the most effective control method is to prevent the concrete surface from drying out until finishing operations have been completed and curing initiated. The use of an evaporation retardant, such as CONFILM®, temporary wet coverings, waterproof sheeting or a fog spray can be beneficial in this regard.

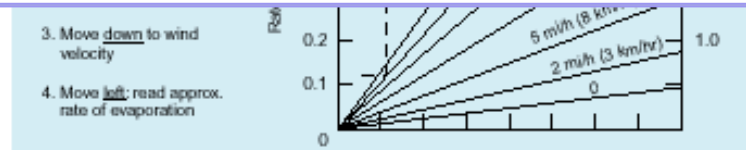


FIGURE 1. Effect of Concrete and Air Temperatures, Relative Humidity, and Wind Velocity on the Rate of Evaporation of Surface Moisture from Concrete [1].

# Bridge Deck Cracking

## What is being addressed

- ◆ New guidelines have been given to the SR
- ◆ METS is researching other alternatives to fly ash for ASR mitigation
  - ◆ Lithium
- ◆ Aggregate site testing for ARS
- ◆ Discussion Topic at the OSC Bridge Contractor Forum in 2001
  - ◆ Information on OSC website
- ◆ Continued discussion at AGC meetings



## ◆ Structure Representatives

- ◆ Discuss deck curing issues at start of project
  - ▶ Including cement VS cementitious
- ◆ More frequent testing & monitoring of curing compounds
- ◆ Process CCOs to implement present specification changes
- ◆ Monitoring set times of trial batches

# Bridge Deck Cracking

## Conclusions

- ◆ Cracking is more Methods than Materials
- ◆ Contractors and suppliers
  - ◆ Communication breakdown
  - ◆ Relying on “same old” procedures
- ◆ Prompt application of water cure is essential
- ◆ Proper handling & application of curing compound is essential
- ◆ Additional alternatives should be developed and publicized
  - ◆ Finishing agents - MB CONFILM
  - ◆ Shrinkage reducing admixtures – MB Tetraguard

Thank you

QUESTIONS